COASTAL BENTHIC OPTICAL PROPERTIES: OPTICAL PROPERTIES OF BENTHIC MARINE ORGANISMS AND SUBSTRATES

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LONG-TERM GOALS

This project is a part of the ONR Environmental Optics Department Research Initiative (DRI) in Coastal Benthic Optical Properties (CoBOP). The long-term goals for the effort under this award are three-fold:

1) Gaining an understanding of the phenomenology and processes related to optical properties (fluorescence and reflectance) of corals and associated benthic organisms and substrates. The interest is in understanding the underlying biology of the pigmentation and how that biology contributes to the nature and variability of spectral signatures;

2) Relating the optical properties of benthic marine organisms and substrates to the signals received by either in-water or airborne remote sensing systems operating in active or passive modes;

3) Ensuring the overall success of the CoBOP effort. The PI is the designated lead coordinator (chief scientist) for the CoBOP DRI and coordinator for the coral reef subgroup. The long-term goal is successful organization, execution, data analysis, documentation and publishing of the CoBOP project.

SCIENTIFIC OBJECTIVES

Specific objectives were related to each of the three long-term goals described above:

1) Determine what we have learned to date about coral fluorescence and reflectance as guidance for the upcoming CoBOP fieldwork that will commence in 1998. The 1995 and 1996 CoBOP field campaigns produced data that had not yet been fully analyzed. The intent of the analysis was to assist in framing clear questions to be addressed in future fieldwork, and to determine how well the Benthic SpectroFluorometer (BSF) (Mazel, 1997b), one of our primary data collection instruments, has been functioning.

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2) Determine what our existing data can tell us about the performance of the Fluorescence Imaging Laser Line Scanner (FILLS) (Strand et. al, 1997).

3) Formulate specific plans for CoBOP DRI field research in preparation for the first of four field campaigns, which will take place in May/June 1998, and establish efficient means of communication for the group to enhance the planning process.

APPROACH

No fieldwork was conducted this year under this award. Data collected in the 1995 and 1996 field campaigns at the Dry Tortugas were examined in a number of ways in order to meet the stated objectives.

Coral optics data:

Data were summarized to determine what data, and of what quality, we already hold. Data were examined in a number of ways, primarily to determine variability in fluorescence and reflectance response within and between species. In situ data collected with the BSF were compared with measurements made with a laboratory spectrofluorometer to determine data quality.

In many cases corals contain more than one fluorescent pigment (Mazel, 1997a), in varying amounts. A measured emission spectrum will be the sum of the fluorescence responses of each of the contributing pigments. Each of the pigments has a different excitation spectrum, however, so a change in excitation wavelength would be expected to result in a change in both the intensity and shape of the composite emission spectrum. Mathematical routines in MATLAB were developed to 'dissect' emission spectra to determine how much each of the fluorescent pigments is contributing to the composite spectrum. The method uses a least-squares minimization routine and prototype emission spectra for each of the pigments. Additional routines are being developed to predict the shape and magnitude of the expected emission spectrum for any excitation wavelength based on the measured response at any other excitation wavelength and knowledge of the characteristics of the excitation light sources.

FILLS data:

Raw FILLS image data were acquired from Coastal Systems Station. Processing and analysis of the images were done using the ENVI and MATLAB software packages. Systematic approaches for going from raw to processed scene data are being developed.

First-cut models of FILLS quantitative performance were acquired from Bryan Coles of Raytheon. These nominally provided a measure of fluorescence efficiency for pixels in specific targets. The results from that sensor were compared with our coral fluorescence data in two ways: 1) to see if the determinations of fluorescence yield were at all close to our preliminary measurements, and 2) to see if the three-point 'spectrum' derived from the FILLS data matched fluorescence emission spectra for the same specimens measured with a laboratory spectrofluorometer on shipboard. To compute the expected responses a

mathematical filter corresponding to the bandpass for each of the FILLS interference filters was applied to the measured spectrum and the resulting values integrated over the bandpass.

CoBOP planning:

A site visit was made to the Caribbean Marine Research Center at Lee Stocking Island to determine that location's suitability to host the large-scale CoBOP DRI effort. The shore facilities were investigated and SCUBA dives were made at a variety of sites to determine if the necessary bottom types existed in reasonable proximity to the research station.

Internet resources (world-wide-web site and e-mail) were established to further communication to and among CoBOP researchers. In order to test an approach to data sharing in the long term, a Java program was developed that would enable plotting of ASCII data files on demand over the web. A JavaScript routine that will streamline the interface with the Java program is being developed.

WORK COMPLETED

Coral optics data:

Substantial analysis of prior data has been completed, and the process is still ongoing. The MATLAB routine for separating the fluorescence components is working well and a technical note is being prepared.

FILLS data:

Comparison of FILLS data and our spectral data for individual specimens has been completed, and the results communicated to Bryan Coles. A general assessment of the FILLS sensor in light of our current knowledge of coral fluorescence characteristics, including recommendations for changes, was drafted and distributed (Mazel, 1997c).

CoBOP planning:

The site visit to Lee Stocking Island was completed successfully. The web site for CoBOP planning has been established (see references for site address). A central e-mail site for inter-group communication has been established.

RESULTS

Representative results will be presented here.

Figure 1 shows the result of applying the emission spectrum decomposition routine to a composite emission spectrum measured in the field. The original data (—) and computed individual fluorescent components (+ and o) are indicated. The fit between the summation

of the modeled contributing pigments and the measured spectrum is not shown since the two would be indistinguishable at this scale.

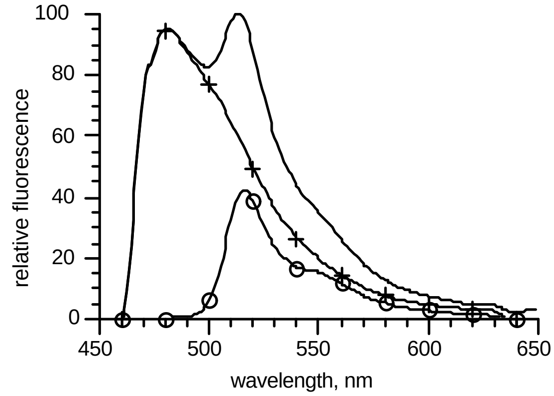

Figure 1

The direct comparison of BSF data with data from the laboratory spectrofluorometer indicate that the former provides valid information but is somewhat limited by low sensitivity. Measurements require long integration times and accompanying large baseline shifts due to dark current and electrical offsets. We are in the process of acquiring a more sensitive spectrometer card for the BSF to improve its performance.

Figure 2 shows the fit between the measured emission spectrum for a specimen ()~~, the~~ value we predict should be measured by FILLS (•), and the values (mean [o] and ± sd) derived by applying the first-cut quantitative model to all of the pixels in the FILLS image of the specimen. The data were normalized to match at the chlorophyll emission peak (685 nm). The set of graphs for all targets examined is being used to refine the FILLS model.

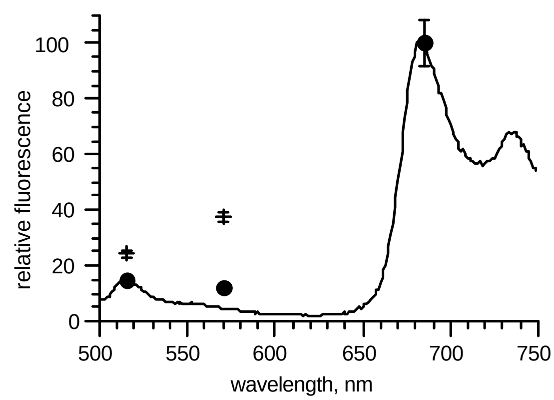

Figure 2

Figure 3 (excerpted from Mazel, 1997c), shows the emission spectrum for the green-fluorescent pigment designated 515'(Mazel, 1997a). Superimposed on the spectrum are the bandpasses of the three FILLS fluorescence filters. This data demonstrates that

substantial signal could be expected to appear in the FILLS ‘yellow’ (center wavelength 570 nm) channel even though there is no ‘yellow-fluorescent’ pigment present.

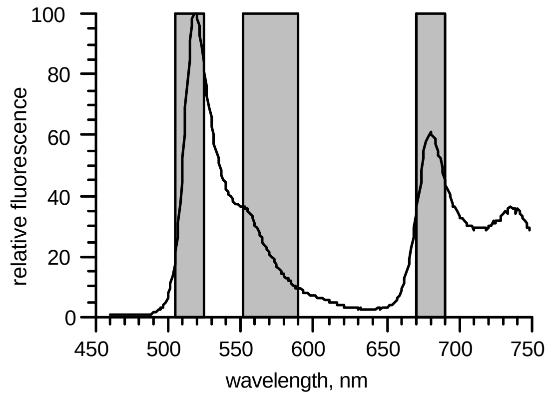

Figure 3

IMPACT/APPLICATIONS

In the long term this research will provide ground truth data for a variety of remote sensing systems that are either in use or under development. The data are already providing guidance for refinements to FILLS. As more data on spectral fluorescence and reflectance signatures are collected as part of the CoBOP project it is hoped that the remote sensing data will be able to provide not only identification of what is on the bottom for search and mapping applications, but also indication of physiological state that will be of use for monitoring of condition of the reef or other environments.

TRANSITIONS

The analysis of the design and performance of the FILLS sensor in light of what we are learning about coral fluorescence (Mazel, 1997c) is assisting fellow CoBOP researchers Bryan Coles (Raytheon) and Mike Strand (Coastal Systems Station) in interpretation of FILLS data. It may also contribute to design of future versions of the system.

RELATED PROJECTS

The results achieved to date through the CoBOP field work have led to interest within the National Oceanic and Atmospheric Administration (NOAA) in applications of fluorescence techniques to coral reef problems. Funding from the MIT Sea Grant program and support (ship time and Nitrox diving) from NOAA enabled participation in a one-week cruise to the Dry Tortugas in June 1997. Data (primarily visual identifications and videotape) were collected to complement the 1996 FILLS survey at a NOAA transect

site. New combinations of excitation lights and barrier filters were tested with the goal of enhancing capabilities for divers to use fluorescence to locate juvenile corals (spat) in the 1 - 5 mm size range.

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